The effects of chronological age, slaughter weight, and gender on lamb: A review

L.E. JEREMIAH
Research Centre
Lacombe Alberta

Technical Bulletin 2000-1E

Research Branch
Agriculture and Agri-Food Canada
2000

Agriculture and Agri-Food Canada Agriculture et Agroalimentaire Canada

Canada

Copies of this publication are available from
Director Lacombe Research Centre
6000 C&E Trail
Lacombe, Alberta
T4L 1W1

©Her Majesty in Right of Canada as Represented by
Public Works and Government Services Canada 2000
Cat. No. A54-8/2000-1E
ISBN No. 0-662-29317-7
Printed 2000

101-01169/

The effects of chronological age, slaughter weight, and gender on lamb: A review

L.E. JEREMIAH
Research Centre
Lacombe Alberta

Technical Bulletin 2000-1E

Research Branch
Agriculture and Agri-Food Canada
2000

Copies of this publication are available from
Director Lacombe Research Centre
6000 C&E Trail
Lacombe, Alberta
T4L 1W1

©Her Majesty in Right of Canada as Represented by
Public Works and Government Services Canada 2000
Cat. No. A54-8/2000-1E
ISBN No. 0-662-29317-7
Printed 2000

SUMMARY

A comprehensive review of the literature on the effects of chronological age, slaughter weight, and gender on lamb has revealed the industry must produce and market younger and leaner lambs if it is to maintain and expand its market share. To achieve this goal it will be necessary to be cognizant of the interactions existing between biological type, chronological age, slaughter weight and gender in the utilization of genetics and nutritional regimes, to produce lambs with maximum consumer appeal, and to market lambs between 3 and 12 months of age with slaughter weights between 59 and 68 kg. Effective classification of carcasses for both quality and yield will also substantially augment the effort.

RÉSUMÉ

Le compte rendu d'une recherche documentaire sur les effets de l'âge réel, du poids d'abattage et du sexe sur l'agneau, révèle que l'industrie devra produire et promouvoir un agneau plus maigre et plus jeune si elle veut maintenir et accroître sa part du marché. Afin d'atteindre ce but, il sera nécessaire de reconnaitre les interactions entre le type d'animal, l'âge réel, le poids d'abattage et le sexe, afin d'utiliser la génétique et des régimes alimentaires adéquats pour produire un agneau qui plaira au consommateur ainsi que pour la mise en marché d'agneaux agés de 3 à 12 mois et d'un poids d'abattage entre 59 et 68 kg. De plus, une classification efficace des carcasses basée sur la qualité et le rendement améliorera de façon substantielle, la commercialisation du produit.

Table of Contents

Background 1

Composition 1

Yield and Cutability 2

Carcass Measurements 3

Carcass and Meat Quality 6

Retail Acceptability 8

Cooking Properties and Palatability 9

Consumer Acceptance 12

Summary and Conclusion 13

Acknowledgement 13

References 13

List of Tables

Table 1. The effects of slaughter weight and gender on the percent of respondents indicating an unwillingness to purchase packages of rib chops 2

Table 2. Percentages of leg roasts which received unacceptable ratings for overall palatability from consumers for various traits. 8

Background

The population of lambs currently being commercially produced and marketed are a mixture of three genders (rams, ewes, and wethers) with chronological ages and slaughter weights ranging from less than three to fifteen months and 30 to 75 kg, respectively. The Canadian commercial lamb population has a considerably different breed composition from populations produced in the southern hemisphere (New Zealand and Australia). Consequently, lambs in Canada are marketed at considerably heavier weights. Consumer preferences for Canadian and southern hemisphere lambs have been clearly documented based upon palatability (Jeremiah 1988). Briefly southern hemisphere lamb was preferred for texture, probably as a result of additional postmortem aging, and Canadian lamb was preferred for flavour probably as a result of more time on feed.

Carpenter (1966) expressed a need for definitive research to provide guidelines for optimizing the balance between carcass weight, quantitative yield of retail cuts, and meat quality. Fatness and muscling of lamb carcasses vary widely, due to differences in age, breed, slaughter weight, gender, and preslaughter management and nutrition (Carpenter 1966).

The goal of this review is to provide a current assessment of the effects of chronological age, slaughter weight, and gender on lamb, carcass composition and meat quality. This review will cover in detail the influences of chronological age, slaughter weight, and gender on sical and chemical composition, yield and cutability, carcass measurements, carcass and meat quality, retail acceptability, cooking properties and palatability, and consumer acceptance. In addition, the most recent findings will be compared with and related to previous findings.

Composition

Although many studies have evaluated the influence of factors such as age, weight, breed, gender, and diet on carcass composition (Burton and Reid, 1969; Wood *et al.* 1980), these studies have tended to utilize relatively small, specific samples of the population and to only evaluate one or two factors in isolation. Both Notter *et al.* (1983) and Thompson *et al.* (1979) observed negative relationships between carcass lean content and slaughter weight. Thompson *et al.* (1979) also observed negative trends between slaughter weight and the proportion of carcass bone, and positive trends between slaughter weight and the proportion of carcass fat. Other reports have indicated carcass fat content increased lineally with slaughter weight in young lambs (Wise 1978; Notter *et al.* 1983), Thompson *et al.* (1979) observed positive trends between slaughter weight and the proportion of subcutaneous and intermuscular fat. Other reports have indicated ram lambs were generally the leanest and ewe lambs were generally the fattest of the three gender classes at any weight (Andrews and Orskov 1970; Butler-Hogg *et al.* 1984; Carpenter *et al.* 1969; Chrystall and Winger 1986; Kemp *et al.* 1962; Lewczuk *et al.* 1980; Purchas 1978; Walker 1950; Wise 1978), and Thompson *et al.* (1979) reported wethers to have a higher proportion of carcass bone than ewes. Wether lambs have also had more subcutaneous fat than ram lambs (Carpenter *et al.* 1969; Kemp *et al.* 1962; Walker 1950). Other reports have indicated wether lamb carcasses had a higher proportion of body cavity fat than carcasses from ram lambs (Carpenter *et al.* 1969; Kemp *et al.* 1962; Walker 1950).

Until recently, there has been no comprehensive study completed to examine the influences of these inherent traits on the carcass composition of a sample representative of the commercial lamb population. In a recent Lacombe study a total of 1660 lambs, representative of the Canadian market lamb population, were slaughtered and separated into wholesale cuts, which were subsequently physically separated into lean, fat, and bone. In addition, the total carcass lean was chemically analyzed for moisture, fat, and protein (Jeremiah *et al.* 1997a). Trends observed in carcass lean content with advancing chronological age indicated, if rams and wethers are to be marketed at light weights, they should come from large late-maturing breed types and be marketed at young ages. Also, if rams are to be marketed at heavy weights, they should receive a low plane of nutrition and be marketed at older ages, to prevent overfinishing. These results are in general agreement with previously reported results from studies of the effects of nutrition on body composition (Andrews and Orskov 1970) and the effects of age (Riley *et al.* 1972) and slaughter weight (Steele and Hohenboken 1972; Vesely and Peters 1972) on carcass composition, whereby increases in

age and slaughter weight usually result in higher levels of fatness unless the plane of nutrition is reduced.

Negative trends in carcass lean content with increasing liveweight reported by Jeremiah *et al.* (1997a) clearly represent an obstacle to the production and marketing of young, heavyweight lambs to increase production efficiency. Observed trends by Jeremiah *et al.* (1997a) further substantiate the fact that rams produce leaner carcasses than wethers, which in turn produce leaner carcasses than ewes.

Yield and Cutability

Significantly greater monetary returns could be obtained by all segments of the lamb industry from production and utilization of leaner, higher yielding lambs (Carpenter 1966). Moreover, a recent consumer survey demonstrated the population of market lambs currently being produced and marketed in Canada are too fat to suit the vast majority of consumers (Jeremiah *et al.* 1993, Table 1).

The ultimate desirability of a lamb carcass is determined by the yield of edible portion and the quality of the muscles which comprise this portion (Carpenter, 1966). Numerous reports have suggested various quantitative and compositional criteria of ultimate carcass desirability including: carcass value (Carpenter *et al.* 1964; Oliver *et al.* 1967; Ringkob *et al.* 1964), total retail cuts (Oliver *et al.* 1967; Ringkob *et al.* 1964), trimmed primal retail cuts (Spurlock and Bradford 1965; Spurlock *et al.* 1966; Zinn 1961; Cunningham *et al.* 1967; Carpenter *et al.* 1964; Hoke 1961), weight of edible meat per day of age (Carpenter *et al.* 1965), edible portion (Judge and Martin 1963; Johnston *et al.*, 1967), separable physical components (Moody *et al.* 1965; Judge *et al.* 1966; Field *et al.* 1963; Hankins 1947; Orme *et al.* 1962; Palsson 1939; Barton and Kirton1958; Ringkob *et al.* 1964; Timon and Bichard 1965; Walker and McMeekan 1944) and chemical composition (Hankins 1947; Khandeker *et al.* 1965; Pradhan *et al.* 1966; Munson *et al.* 1966; Adams *et al.* 1967, 1970). Many studies have evaluated the influence of inherent factors such as chronological age, gender, carcass weight, breed, and management on carcass composition and the above measures of carcass desirability (Burton and Reid 1969; Jeremiah *et al.* 1997a; Wood *et al.* 1980).

Table 1
The effects of slaughter weight and gender on the percent[a] of respondents indicating an unwillingness to purchase packages of rib chops (from Jeremiah 1988)

Liveweight	Reasons not to purchase[b]						
	1	2	3	4	5	6	7
Ram							
40.5-49.5kg	29.8	10.7	0.2	56.3	2.6	0.4	0.0
50.0-58.6kg	68.6	6.4	0.1	21.5	3.2	0.0	0.1
58.9-67.7kg	92.8	1.6	0.5	3.0	1.8	0.3	0.1
68.2-76.8kg	97.9	0.4	0.5	0.6	0.4	0.1	0.1
All	82.5	3.1	0.4	12.1	1.6	0.2	0.1
Ewe							
40.5-49.5kg	94.5	0.5	0.5	3.4	1.0	0.1	0.0
50.0-58.6kg	96.5	0.5	0.6	1.8	0.6	0.0	0.0
58.9-67.7kg	98.4	0.1	0.5	0.9	0.2	0.0	0.0
68.2-76.8kg	98.2	0.3	0.5	0.9	0.2	0.0	0.0
All	97.0	0.3	0.5	1.7	0.5	0.0	0.0
Wether							
40.5-49.5kg	84.1	2.2	0.4	12.4	1.0	0.0	0.0
50.0-58.6kg	92.5	1.1	0.5	5.3	0.4	0.1	0.1
58.9-67.7kg	93.8	1.4	0.5	3.1	1.0	0.0	0.1
68.2-76.8kg	97.7	0.3	0.5	0.9	0.5	0.1	0.0
All	92.8	1.1	0.5	4.9	0.7	0.0	0.0
All sexes							
40.5-49.5kg	81.3	2.6	0.4	14.4	1.2	0.1	0.0
50.0-58.6kg	89.9	1.8	0.5	6.8	1.0	0.0	0.1
58.9-67.7kg	95.7	0.8	0.5	2.1	0.8	0.1	0.1
68.2-76.8kg	98.0	0.3	0.5	0.8	0.4	0.1	0.0
All	92.2	1.3	0.5	5.2	0.8	0.1	0.0

[a]Expressed as a percent of row total.
[b]Reasons not to purchase: 1= too fat, 2 = too lean, 3 = too large, 4 = too small, 5 = poor colour, 6 = too much bone, 7 = excessive purge

Notter *et al.* (1983) demonstrated carcass and trimmed cut yields were influenced by both breed and feeding regime and indicated slaughter weights which optimized trimmed cut yields from ram lamb carcasses of three early maturing breeds (40.5 kg for Dorset, 40.7 kg for Rambouillet, and 34.7 kg for Finnish Laudrace), Jeremiah *et al.* (1997b) observed inconsistent differences in the proportion of hindsaddle and longsaddle attributable to gender, which appeared contrary to previous reports that ewe and wether lamb carcasses produced higher hindsaddle yields than ram carcasses (Carpenter *et al.* 1969), probably as a result of ram carcasses having heavier shoulders and ewe and wether carcasses having more subcutaneous and body cavity fat. This disparity in findings probably is due to kidney and pelvic fat being removed prior to cutting in Canada. Carpenter *et al.* (1969) concluded, if hindsaddle yield was adjusted to a constant level of body cavity fat, carcasses of different genders would likely be similar in hindsaddle yields. Various reports have indicated ram carcasses had higher yields of consumer preferred cuts than ewe and wether carcasses (Carpenter *et al.* 1969; Cunningham *et al.* 1967; Ray and Mandigo 1966). However, Carpenter *et al.* (1969) reported ram lamb carcasses to have a higher proportion of shoulder. Some reports have indicated ewe and wether carcasses differed in cutability (Boylon and Seale 1965; Oliver *et al.* 1967; Field *et al.* 1963), but other reports have indicated ewe and wether carcasses were similar in cutability (Carpenter *et al.* 1969; Judge *et al.* 1966; Knight and Foote 1965). Jones *et al.* (1996) evaluated 236 ewe and wether carcasses (18 to 30 kg warm carcass weight) and reported ewe carcasses had lower saleable meat yields, as a result of ewe carcasses having more (2.6 to 17.9%) kidney fat in all weight and fatness groups. They also reported saleable meat yield decreased with fatness, but slaughter weight exerted little influence on saleable meat yields within fatness groups.

Until recently, there have been no comprehensive studies completed to examine the influence of inherent traits on the yield and cutability of a representative sample of the market lamb population. A recent Lacombe study evaluated 1660 lambs of three genders in four chronological age and five slaughter weight groups for antemortem preslaughter shrink; dressing yield and cutability (Jeremiah *et al.* 1997b). Although these traits are likely a function of interactions of age, weight, and gender, dressing yields decreased as slaughter weight increased and were lowest for ram lambs. Ram lambs generally had the lowest proportions of loin, rack, and flank; and the highest proportions of shank, while ewe lambs had the highest proportion of rack. Proportions of hindsaddle and longsaddle decreased with slaughter weight in young lambs (<9 months). Proportion of leg also decreased with advancing age in heavyweight ram and ewe lambs (≥68.2 kg live). Proportion of loin decreased with advancing age in heavyweight lambs (>50 kg live) and increased with slaughter weight in young rams (<9 months). Proportion of rack also decreased with advancing age, in lightweight lambs (<58.9 kg live). Proportion of breast was not influenced by either slaughter weight or chronological age but proportion of flank increased with advancing age. Proportion of shoulder increased with advancing age particularly in rams over 40 kg at the time of slaughter. Proportion of shank decreased with slaughter weight in young lambs (<12 months) and increased in older lambs (>12 months). Proportion of shank also decreased with advancing age in lightweight lambs (<50 kg live) and increased in heavyweight wether lambs (≥68.2 kg live).

Carcass Measurements

Since most proposed measures of carcass desirability require the carcass to be broken down into individual cuts or physical or chemical components, various studies have utilized carcass measurements to estimate these measures (Carpenter *et al.* 1964, 1965, 1969; Oliver *et al.* 1967, 1968; Hoke 1961; Field *et al.* 1963; Spurlock and Bradford 1965; Johnston *et al.* 1967; Ringkob *et al.* 1964; Cunningham *et al.* 1967; Judge *et al.* 1966; Spurlock *et al.* 1966; Wise, 1978).

Although the classification or grading of lamb carcasses is based upon subjective evaluation of fatness and muscling in most countries, New Zealand has used measurements of total tissue depth over the twelfth rib, eleven centimeters from the midline (GR site) to identify overfat carcasses since 1973 (Kirton *et al.* 1984). The possibility of including objective measurements, such as fat thickness, total tissue depth, and loin-eye area or depth, as potential predictors of carcass lean content have been considered by several authors (Field *et al.* 1963; Timon and Bichard 1965; Kempster *et al.* 1976; Kirton *et al.* 1984; Bruwer *et al.* 1987), who reported varying degrees of prediction accuracy. For example, Kempster *et al.* (1976) concluded visual scores for carcass fatness had similar precision for prediction of carcass lean content as fat measurements.

Loin-eye area is an important trait to consumers, particularly for lamb, since it relates directly to lean-to-bone ratio in the most valuable cuts (Jeremiah 1982) and has been traditionally utilized as an estimate of muscling in the carcass, and particularly in the most valuable cuts (Carpenter *et al.* 1969; Cunningham *et al.* 1967). Loin-eye area increased with slaughter weight in young ram lambs but decreased with increasing slaughter weight in carcasses from older ram lambs (12 to 15 mo ths) (Jeremiah *et al.* 1997c) probably as a result of the *longissimus* muscle maturing at one year of age in ram lambs (Butterfield *et al.* 1984). Differences in loin-eye areas attributable to gender were not observed in some studies (Ray and Mandigo 1963, 1966). However, other studies have found carcasses from ram lambs to have the largest and carcasses from ewe lambs to have the smallest loin-eye areas (Carpenter *et al.* 1969; Field 1971; Spurlock and Bradford 1965; Field *et al.* 1967; Judge *et al.* 1966). However, Wise (1978) observed carcasses from wether lambs to have larger loin-eye areas than carcasses from ewe lambs. Other reports have indicated increasing slaughter weight was associated with larger loin-eye areas (Wise 1978).

Carpenter *et al.* (1969) reported ram lamb carcasses to have less subcutaneous fat than ewe and wether carcasses. Various other reports have indicated ewe lamb carcasses were generally fatter than ram and wether carcasses (Carpenter *et al.* 1969; Kemp *et al.* 1962; Walker 1950; Wise 1978). Wise (1978) and others have concluded increasing slaughter weight was associated with greater carcass fatness.

Since lamb carcasses traditionally have not been broken in commerce, it has not been possible to measure actual subcutaneous fat thickness. Consequently, it has been often estimated subjectively or measured on the warm or cold carcass. Some British studies (Chadwick *et al.* 1986; Kempster *et al.* 1976, 1986) have indicated visual assessment of lamb carcass fatness predicted the proportion of carcass lean with equal or greater precision than measures of total tissue depth, and Kempster *et al.* (1976) suggested an advantage fro using both visual assessment and actual measurement.

The meat industry traditionally has paid more for carcasses with superior conformation, and breeders and meat traders still attach importance to conformation as an indicator of commercial value, based upon the belief conformation reflects lean-to-bone ratio and muscle thickness (Kempster *et al.* 1982). By definition conformation generally reflects lean-to-bone ratio and muscle thickness, but when subjective visual conformation scores are based upon a limited range of fatness, conformation scores identify fat rather than lean carcasses (Kempster *et al* 1982). In addition, conformation has little value as a predictor of the lean content of the most valuable cuts in the carcass or of carcass composition, within breeds (Kempster *et al.* 1982). Furthermore, conformation's relationship to lean content is dependent upon control of variation in fatness, since fatter carcasses tend to receive higher conformation scores. However, fat-corrected conformation has been reported not to be a valuable predictor of carcass composition (Kempster *et al.* 1982; Garrett *et al.* 1992; Jones *et al.* 1992). Despite these findings, Jones *et al.* (1996) concluded conformation provided a small but useful increase in the precision of prediction of saleable meat yield. However, Kempster *et al.* (1982) concluded conformation was an inaccurate indicator of carcass muscling in carcasses from ewe and wether lamb carcasses, due to greater subcutaneous fat cover. Moreover, since both conformation and muscling scores closely paralleled subcutaneous fat cover (Jeremiah *et al.* 1997c), it is surprising Carpenter *et al.* (1969) reported ram carcasses were more muscular than ewe carcasses.

Hopkins and Fogarty (1998a,b) reported genotype significantly influenced carcass measurements, conformation, and lean meat yields and Purchas and Wilkin (1995) observed improved muscularity scores to slightly increase meat yields. Jones *et al.* (1996) concluded total tissue depth over the twelfth rib (GR measurement) combined with conformation score, predicted saleable meat yield with the greatest accuracy ($r^2 = 0.61$) and reported the accuracy of predictors could be improved by removing kidney fat from carcass weight. Hopkins (1994) observed estimated lean yields was correlated among genotypes ($r = 0.97$) and reported GR measurement, loin-eye area, and hot carcass weight in combination accounted for breed type differences in lean meat yields.

Electronic grading probes have been developed and adopted in many countries for grading pork carcasses, and their utility under industrial conditions has been proven. Consequently, similar technology may be of value for the grading of commercial lamb carcasses. Jones *et al.* (1992) reported the Hennessey grading probe explained 40 to 64% of the variation in carcass lean content and 44 to 72% of the variation in carcass fat content. Fat thickness or total tissue depth measurements with the Hennessay probe between the twelfth and thirteenth ribs were superior to visual

assessment of carcass fatness for predicting carcass lean content and permitted carcasses to be classified on the slaughter floor (Jones *et al.* 1992). Kirton *et al.* (1995) reported electronic probes in combination with carcass weight accounted for 36 to 49% of the variation in carcass fat and moisture, respectively, while manual GR measurement accounted for 55% of the variation in carcass moisture and 58% of the variation in carcass fat content. Hopkins *et al.* (1993) reported operator effort and care was important to the accuracy of electronic probe measurements. In an Australian study, when operators used a probe which probed to the rib rather than between ribs, the twelfth rib, was probed in only 30% of the cases at line speed (Hopkins *et al.* 1993). The thirteenth rib was probed a majority of the time, but in only 2% of the cases was the probe site more than one rib away from the twelfth rib. In 67% of the cases carcasses were probed 11 cm off the midline, and up to 90% of the electronic probe measurements were within 2 mm of the manual measurements.

Although numerous studies have investigated the effects of various inherent factors including chronological age, slaughter weight, and gender on carcass measurements, until recently, there have been no comprehensive studies conducted, which have evaluated the combined effects of these inherent traits on carcass measurements of a sample representative of the market lamb population. A recent Lacombe study evaluated the effects of these inherent factors on various carcass measurements of 1660 lamb carcasses, representative of the Canadian market lamb population. Warm carcass lean depth measured with the Hennessy probe between the twelfth and thirteenth thoracic vertebrae was greatest in wether lambs and least in ram lambs; and generally increased in all lambs with slaughter weight, and in ewe and wether lambs with advancing age (Jeremiah *et al.* 1997c). Cold carcass lean depth was generally least in ram lambs, and not related to either slaughter weight or chronological age. Ram lambs generally had the least loin-eye width. Loin-eye width (dorsal-ventral) increased with slaughter weight in older wether lambs (≥9 months), but decreased with slaughter weight in older ram lambs (≥12 months). Loin-eye width also decreased with advancing age in ram lambs 59 to 68 kg and wether lambs 50 to 59 kg at the time of slaughter. Ram lambs had the longest and ewe lambs had the shortest loin-eyes. Loin-eye length (lateral-medial) increased with slaughter weight in young lambs (≤9 months), and with advancing age in wether lambs over 40 kg at the time of slaughter. Although loin-eye area did not differ among genders, it increased with slaughter weight, except in older ram lambs (≥12 months), when it decreased. Loin-eye area was generally not related to chronological age. Ram lambs generally had the lowest GR total tissue depth measurements in the warm carcass. GR total tissue depth measurements increased with slaughter weight in young wether lambs (<9 months), but was generally not related to chronological age. Ewe lambs had the greatest body wall thickness and ram lambs had the least. Body wall thickness generally increased with slaughter weight, but was not related to chronological age.

Ewe lambs were subjectively estimated to have the greatest subcutaneous fat thickness, and ram lambs were estimated to have the least. External fat thickness increased with slaughter weight, but was generally not related to chronological age. Ewe lambs had the most and ram lambs had the least warm and cold carcass fat thickness, measured with the Hennessy probe. Warm carcass fat thickness generally increased with slaughter weight in young lambs (≤9 months), and decreased with advancing age in heavyweight ram lambs (≥58.9 kg live). Cold carcass fat thickness increased with slaughter weight, particularly in wether lambs, but was generally not related to chronological age. Ewe lambs had the greatest and ram lambs had the least subcutaneous fat thickness measured with a ruler on the cold carcass 1.5 cm from the midline between the twelfth and thirteenth thoracic vertebrae (MFT). MFT generally increased with slaughter weight, but was not related to chronological age. Ewe lambs also had the most and ram lambs had the least subcutaneous fat thickness, measured with a ruler on the cut loin surface 1.5 cm from the midline between the twelfth and thirteenth thoracic vertebrae (AFT). AFT generally increased with slaughter weight in young lambs (≤9 months), but was generally not related to chronological age.

Ewe lambs generally received the highest and ram lambs generally received the lowest conformation and muscling scores. Conformation and muscling scores generally improved with slaughter weight, but were not related to chronological age. However, ram lambs apparently became less well muscled with advancing age, after they reached 50 kg in slaughter weight, and this decrease in muscling was not attributable to differences in breed on genotype.

Measurements of fat thickness explained 40 to 64% of the variation in carcass lean, and, 44 to 72% of the variation in carcass fat, depending on the location, number of measurements, and whether taken on warm or cold carcasses. In most cases, when measurements of muscle thickness were added to measurements of fat thickness, there was no increase

in the amount of variation explained in carcass composition, over that provided by measurements of fat thickness alone (Jones *et al.*, 1992). Total tissue depth measurements varied in the precision with which they predicted carcass lean content, with measurements taken at the twelfth rib being superior to measurements taken at the tenth rib. Visual assessment of carcasses for fatness had the lowest precision for prediction of lean content. Loin-eye area and fat thickness measured at the twelfth rib had similar precision for estimating carcass lean content as probe measurements. Consequently, probe measurements of fat thickness or total tissue depth measured between the twelfth and thirteenth ribs provided a superior means for estimating carcass lean content over visual assessment of carcass fatness, and permits carcasses to be graded for yield on the slaughter floor.

Carcass and Meat Quality

The ultimate desirability of lamb carcasses is determined by the yield of edible portion and the quality of the muscles which comprise this portion, as it relates to palatability and consumer acceptance. However, it is clearly evident lamb carcasses differ considerably in muscling and fatness, due to differences in age, weight, breed, gender, management and nutrition (Carpenter *et al.* 1969), and as outlined above.

Channon (1990) reported production of larger lamb carcasses would increase profitability, and Bruwer *et al.* (1987) reported the influence of carcass weight on meat quality over a wide weight range was generally negligible. Purchas *et al.* (1979) also reported differences in meat quality attributable to slaughter weight and chronological age were small. Sanudo *et al.* (1996) indicated carcass weight did not influence water holding capacity. However, Kemp *et al.* (1976) indicated both slaughter weight and gender influenced overall carcass quality, and Ray and Kromann (1971) reported carcass conformation, ribcage feathering, marbling, and carcass grade increased with time on feed. Sañudo *et* al. (1996) observed increases in muscle pH and darker, redder lean colour with increases in slaughter weight, and Jacobs (1972) reported the consumer acceptance of lamb from wethers increased with slaughter weight. However, Chanon (1990) reported 45% of the retailers in an Australian survey would not purchase larger lamb carcasses, due to excessively large primal and retail cuts and the perception, larger lamb carcasses were overfat and had lower meat quality.

Various reports have also indicated genders did not differ in meat quality (Anonymous 1984), and Dransfield *et al.* (1990) reported marbling and muscle colour did not differ due to gender. However, Wiggins *et al.* (1976) observed ewe carcasses to have more marbling than ram and wether carcasses, and wether and ewe carcasses to have firmer muscle than ram carcasses.

Although reports have indicated production of entire male sheep resulted in faster production of leaner meat (Anonymous 1984), Kruggel *et al.* (1982) observed ram lambs to accumulate more lutein in their fat depots, which resulted in ram carcasses having yellower fat than wether carcasses. Busboom *et al.* (1981) and Crouse *et al.* (1981) also reported ram carcasses to have softer, yellower fat than wether carcasses. Jabet (1993) reported soft, yellow fat intensified flavour and made cut preparation more difficult, and Crouse *et al.* (1981) indicated gender differences in fat softness were exacerbated by advancing chronological age.

Therefore, many studies have examined the effects of chronological age, slaughter weight, and/or gender on carcass and meat quality (Burton and Reid 1969; Wood *et al.* 1980). However, these studies have tended to utilize relatively small select populations and have tended to evaluate one or two factors in isolation. Until recently there have been no comprehensive studies completed to examine the influence of such traits on carcass and meat quality of a sample representative of the market lamb population. A recent Lacombe study utilized 1660 lambs of three genders in three chronological age groups and four slaughter weight groups for this purpose (Jeremiah *et al.* 1997d). Ram lambs produced the highest proportions of Canada A1 and A2 carcasses and ewe lambs produced the highest proportions of Canada A3 and A4 carcasses. Ewe lambs generally had the most uniform fat covers, while ram lambs generally had the least uniform fat covers. Uniformity of fat cover generally increased with slaughter weight, but decreased with advancing age in heavyweight ram lambs ($\geq$58.6 kg live) (Jeremiah *et al.* 1997e). Ram carcasses generally had the least white fat and produced the highest proportion of carcasses with yellow fat. The fat on heavyweight lambs (<67.7 kg) became less white with advancing age, but became whiter with increasing slaughter weight on rams 3 to 6 and 9 to 12 months of age and ewes 3 to 6 months of age. Ewe lambs generally had the most marbling, ribcage feathering, and flank streaking, the firmest flanks, and the most opaque ribcages, while rams were at the other extreme. Marbling increased with slaughter

weight in older ram and ewe lambs (>12 months) and decreased in young ram and wether lambs (<9 months); flank streaking increased with slaughter weight in young lambs (<9 months), and ribcages became more opaque with increasing slaughter weight, particularly in young lambs (<9 months). Ewe lambs were the most physiologically mature, based upon dentition, at heavy weights and older ages (>9 months). Ewe lambs also generally had the flattest ribs and the least amount of colour on their ribs, and the highest incidence of spooljoints at older ages (>9 months) and heavy weights (≥68.2 kg). The ribs of heavyweight rams (>50 kg) became whiter with advancing age. Sacral ossification and rib colour scores were most highly related to chronological age, but accounted for only 22 and 16% of the variation, respectively. Breakjoint score was the only physiological maturity indicator not related to chronological age. Percent transmission of carcass lean, an indicator of functional and water holding properties, increased with advancing age in ram and wether lambs slaughtered between 32 and 40 kg and in ewes exceeding 68 kg in slaughter weight. Expressible juice tended to increase with advancing age and the carcass lean from ram lambs had the most expressible juice, while carcass lean from ewe lambs had the least. Ram lambs generally had the lightest coloured and most yellow loin-eyes. Loin-eye colour became darker with increasing slaughter weight in young rams and ewes (≤9 months) and lighter in older ewe and wether lambs (≥9 months). Loin-eye colour also became lighter with advancing age in heavyweight lambs (≥67.7 kg). The redness of loin-eyes increased with slaughter weight only in older wether lambs (>12 months), but increased with advancing age. The yellowness of loin-eyes decreased with slaughter weight in young lambs (<12 months), and increased in older wether lambs (>12 months).

Grading standards usually provide the basis for merchandising and assist untrained consumers in the selection of meat cuts to provide eating satisfaction. However, several reports have indicated consumers are satisfied with meat purchases regardless of grade, if they are tender, flavourful, lean, and appealing to the eye, (Dunsing 1959; Lane and Walters 1958; Naumann *et al.* 1961; Seltzer 1955; Van Syckle and Brough 1958).

Hodge and Oddie (1984) reported a classification system requires only information on carcass weight and kidney and channel fat to segregate carcasses into groups differing in economic value. However, Barwick (1980) indicated measures of carcass weight, length, fatness, and shape did not appear adequate criteria upon which to base lamb grading.

Carpenter (1966) reported U.S.D.A. quality grades for lamb carcasses furnished little more than a common language for rather broad groups of carcasses, which were quite variable in cutability, quality, and consumer acceptability, and Fienup *et al.* (1963) reported there was insufficient information to accurately define optimum lamb carcass grades. Several other reports have shown low relationships between lamb quality grades and palatability characteristics (Carpenter and King 1965a,b; Crouse *et al.* 1982; Forrest 1962; Jeremiah *et al.* 1972; Weller *et al.* 1962). However, Paul *et al.* (1964a,b,c) reported cuts from U.S. Choice lambs were significantly more acceptable in colour, juiciness, tenderness, texture, and overall acceptability than those from U.S. Good grade lambs. Smith *et al.* (1970) reported cuts from U.S. Prime carcasses sustained the lowest cooking losses and had the highest proportion of desirable ratings for juiciness, tenderness, and overall satisfaction. In addition, Paul *et al.* (1964a,b,c) found much less difference in eating quality between cuts from U.S. Choice and U.S. Good carcasses than between cuts from U.S. Choice or Good and U.S. Utility carcasses.

A recent Lacombe study was designed to develop a quality classification system for lamb carcasses based upon consumer acceptance. A total of 1660 commercial lambs (>95% black/white face crossbreeds) were selected on the basis of age, weight, gender, and fatness to be representative of the Canadian market lamb population (Jeremiah, 1998c). Based upon the findings obtained, lamb should be defined as carcasses from ovines weighing 32 kg live or more and with no more than two (2) permanent incisors. Mutton should be defined as carcasses from ovines with more than two (2) permanent incisors or carcasses from ovines that have lost their third temporary incisor. Milk-fed lamb should be defined as carcasses from ovines weighing less than 32 kg live. Consequently, classification recommendations arising from the Lacombe study apply only to carcasses from ovines defined as lamb, according to the previous definitions. Lamb carcasses so defined can be effectively segregated into three (3) quality groups based upon expected consumer acceptance, utilizing simple, subjective evaluations of the breakjoints and ribs, as follows: Group 1 possessing very red and moist breakjoints and round, red ribs, Group 2 possessing slightly red to red breakjoints and oval shaped ribs, which are either slightly red or have traces of red colour, and Group 3 possessing white, dry breakjoints and flat, white ribs (Table 2).

Classification of lamb carcasses on this basis will allow compensation to producers based upon carcass merit, reflecting consumer acceptance (Jeremiah, 1998). Group 1 should contain 9% or less of the lamb carcasses being marketed and should receive a premium to reflect a higher degree of consumer acceptance. Group 2 should contain approximately 75% or more of the population of market lambs and be compensated with the prevailing market price. Group 3 should contain 15% or less of the population of market lambs and be compensated with a discount to reflect a lower degree of consumer acceptance.

Table 2
Percentages of leg roasts which received unaceptable ratings (≤2.5) for overall palatability from consumers for various traits (from Jeremiah *et al.* 1998c)

Trait		Type of Roast			
		n	Butt	Shank	All
Breakjoint colour score					
	Very red and moist	169	2.61[b]	7.19	4.90
	Red	1124	7.10[ab]	4.78	5.94
	Slighlty red	292	6.89[ab]	5.84	6.35
	White and dry	75	11.59[a]	11.27	11.43
			(r^2=0.96**)	(r^2=0.36)	(r^2=0.78*)
Rib flatness score					
	Round	147	5.43	7.03	5.23
	Oval	1308	6.67	4.83	5.75
	Flat	205	8.50	8.72	8.61
			(r^2=0.99**)	(r^2=0.19)	(r^2=0.60)
Rib colour score					
	Red	24	4.55	4.76	4.65
	Slighlty red	714	6.45	4.90	5.67
	Traces of red	654	7.03	5.11	6.07
	White	268	7.41	8.06	7.74
			(r^2=0.87*)	(r^2=0.69)	(r^2=0.95**)

[a,b,c] Values in the same column and trait group without a superscript or bearing a common superscript do not differ significantly (P> 0.05).
*P<0.05. **P<0.01.

Retail Acceptability

The population of lambs currently being commercially produced and marketed in Canada are a mixture of three genders (rams, ewes, and wethers) with liveweights generally within the range of 35 to 75 kg (mean = approximately 50 kg). In addition, the Canadian market lamb population consists of a higher proportion of larger, later maturing breeds and breed types than similar populations in the southern hemisphere (New Zealand and Australia). Consequently, lambs in Canada are marketed at considerably heavier weights.

Hopkins *et al.* (1992) observed weekly consumption of lamb varied widely among consumers, and reported 60% of the consumers interviewed preferred bone-in legs, 72% preferred mid-loin chops, and 73% preferred boneless forequarters. Canadian consumer preferences for Canadian and southern hemisphere lamb has been clearly documented, based upon palatability (Jeremiah 1988), but not until recently has it also been based upon appearance at the point of purchase or retail level.

Fatness and muscling of lamb carcasses vary widely, due to differences in age, breed, slaughter weight, gender, and preslaughter management (Carpenter, 1966). However, until recently, no study has been conducted to document consumer preferences regarding criteria used for selection of lamb purchases or the relationship of these preferences to previously cited differences.

Studies evaluating consumer acceptance of lamb are essentially nonexistent in the scientific literature, particularly with regard to the effects of gender, chronological age, and/or slaughter weight on retail acceptability. Mendenhall and Erchanbrack (1979), however, reported carcass weight, sex and breed had no significant effect on consumer acceptance. They also concluded discrimination against lamb carcasses on the basis of weight or sex at best reflects the personal preferences of buyers, packers, feeders and retailers or may reflect lack of uniformity in the trimming of retail cuts.

Although overfat carcasses can usually be made acceptable to consumers through trimming, such a practice produces inefficiencies in both production and processing, and is therefore, extremely costly and

results in higher prices to the consumer. Since excess fat is very costly to both put on animals and to remove from their carcasses and subsequent cuts, a much more efficient system is to produce animals, which yield carcasses, which do not require trimming during processing. This goal is particularly relevant, since one of the greatest problems confronting the lamb industry is price competitiveness with meat from other species and alternate protein sources.

As previously discussed, Wise (1978) reported wether carcasses had larger loin-eyes and were leaner than ewe carcasses. Numerous other reports have demonstrated ram carcasses were generally the leanest and ewe carcasses were the fattest at a given age and slaughter weight (Walker 1950; Kemp *et al.* 1962; Carpenter *et al.* 1969; Andrews and Orskov 1970; Purchas 1978; Lewczuk *et al.* 1980; Butler-Hogg *et al.* 1984; Chrystall and Winger 1986). Wise (1978) also reported increasing slaughter weight was associated with larger rib-eyes and greater fatness. Other reports have also demonstrated increased fatness with increasing slaughter weight (Steele and Hohenboken 1972; Vesely and Peters 1972).

A recent retail survey was conducted to determine the retail acceptability of lamb rib chops from lambs differing in gender and slaughter weight (Jeremiah *et al.* 1993). A random array of 12 packages of untrimmed chops, with equal weight, representative of three genders (rams, ewes, and wethers) and four slaughter weight groups (40.5-49.5; 50.0-58.6; 58.9-67.7; and 68.2-76.8 kg) were presented to 2002 consumers as they passed through 31 supermarkets in two western Canadian cities. Respondents demonstrated an obvious aversion to fatness. Over 50% of the respondents indicated chops from all gender and slaughter weight groups were unacceptable (Table 1, Page 2), with the exception of chops from ram lambs up to 58.6 kg in liveweight at the time of slaughter. Consequently the population of lambs currently being produced and marketed in Canada are too fat to be acceptable to the vast majority of consumers.

Cooking Properties and Palatability

Cooking properties and palatability attributes are major determinants of the acceptability of meat products to consumers, since ultimate consumer satisfaction with a food product is based upon the satisfaction derived at the point of consumption (Jeremiah 1982). Both cooking properties and palatability attributes have been demonstrated to be influenced by factors inherent to the animals from which the products are derived, such as gender, chronological age, and slaughter weight (Jeremiah 1978).

Although Channon (1990) indicated production of larger lamb carcasses would increase profitability for the industry, 45% of Australian retailers declined to purchase larger lamb carcasses due to excessively large primal and retail cuts and their perceived lower meat quality and palatability. Kemp *et al.* (1976) observed increasing slaughter weight to increase total cooking losses, and decrease shear force values. However, Sañudo *et al.* (1998) observed juiciness to increase with carcass weight while all other palatability attributes remained unaffected (Jacobs 1972) reported heavy wethers were more acceptable in palatability than light wethers.

Jacobson *et al.* (1962) reported lamb flavour was primarily an aromatic, described as fragrant oily, sweet, and somewhat musty, and Cramer (1983) concluded lamb flavour was undoubtedly a blend of many compounds produced from chemical components present in lamb and thermal degradation products produced from such components when lamb was cooked. Based upon the complexity of lamb flavour, Crouse (1983) concluded the profile method must be used in lamb flavour research if definitive observations are to be made, since it is an analytical method, which can focus on more than one compound simultaneously, without being influenced by personal preferences or personal opinions regarding acceptability.

Crouse *et al.* (1983) observed "mutton" flavour to become more intense as slaughter weight increased from 50 to 69 kg. However, Weller *et al.* (1962) observed flavour intensity to decrease as slaughter weight increased. Kemp *et al.* (1976) reported the flavour of both ewes and wethers became more desirable as slaughter weight increased from 36 to 54 kg. Other reports have indicated increases in slaughter weight did not influence either shear force values (Wise 1978) or flavour (Crouse *et al.* 1982). Crouse *et al.* (1981) reported increasing slaughter weight of rams and ewes from 62 to 76 kg had no effect on flavour. Mendenhall and Erchanbrack (1979) reported the flavour of rams, ewes, and wethers slaughtered between 41 and 71 kg was highly acceptable to consumers. A portion of the apparent inconsistency in the literature may arise from the fact consumers are divided on their response to intense lamb flavour, with some favoring an intense flavour and others favoring a more bland flavour (Field *et al.* 1982).

Production of entire males has been reported to result in faster, more efficient production of leaner meat (Anonymous 1984), since rams gain faster than ewes and wethers, particularly in the earlier maturing breeds (Dransfield *et al.* 1990). In addition, Kirton *et al.* (1982) observed no differences in the palatability or consumer acceptance of leg roasts attributable to gender, and Butler-Hogg *et al.* (1984) reported the meat from ram and ewe lambs to be equivalent in palatability. Moreover, no undesirable odours were detected from meat from entire male lambs (Alvi 1980; Butler-Hogg *et al.* 1984; Dransfield *et al.* 1990). However, Dransfield *et al.* (1990) reported leg roasts from rams were more acceptable to consumers than their counterparts from ewes and wethers in overall eating satisfaction. Jacobson *et al.* (1962) failed to observe differences in tenderness attributable to gender, but Wise (1978) indicated ewe carcasses had lower shear force values than wether carcasses. Purchas *et al.* (1979) observed slightly higher shear force values in the *semimembranosus* muscle of rams raised on pasture than in equivalent wethers. Other reports have indicated the meat from ewes and wethers (Summers *et al.* 1978; Butler-Hogg *et al.* 1985; Dransfield *et al.* 1990), ewes and rams (Alvi 1980) and rams and wethers (Fox *et al.* 1962; Garrigus *et al.* 1962; Gates *et al.* 1964; Pattie *et al.* 1964; Batcher *et al.* 1969; Alvi 1980) differed in tenderness. Dransfield *et al.* (1990) reported meat from rams had a higher intramuscular collagen content, and Butler-Hogg *et al.* (1985) reported chops from wethers were more juicy than chops from ewes. Alvi (1980) observed no undesirable flavours or aromas attributable to gender. Other reports have indicated genders were similar in flavour and flavour intensity (Wilson *et al.* 1970; Jacobs *et al.* 1972; Wenham *et al.* 1973; Kemp *et al.* 1976; Crouse *et al.* 1978). However, Butler-Hogg *et al.* (1985) indicated chops from wethers were more flavourful than chops from ewes, and other reports have indicated meat from rams had a more intense (Cramer *et al.* 1970; Alvi 1980; Crouse *et al.* 1981) and less desirable (Kemp *et al.* 1972; Misock *et al.* 1976; Pattie *et al.* 1964) flavour. Pattie *et al.* (1964) observed wethers to have a higher incidence of abnormal flavours than rams. However, Jacobson *et al.* (1962) reported wethers to have a more desirable flavour than ewes. A portion of the disparity in previous findings may arise as a result of age/gender/weight interactions. Crouse *et al.* (1983) concluded, after a review of the literature, gender and slaughter weight interactions exerted important influences on lamb flavour. Although, Field (1971) reported flavour difference between rams and wethers to be small and trends not to be apparent in lambs weighing less than 50 kg at slaughter. Charlet (1969) and Batcher *et al.* (1969) observed little difference in the flavour of meat from rams and wethers 8 to 12 and 7 to 16 months of age respectively. Other reports have indicated rams up to 72 kg at slaughter (Crouse *et al.* 1981) and heavyweight rams (Crouse 1983) had more intense flavour. Misock *et al.* (1976) observed chilled ram carcasses to have an "ammonia" or "staggy" aroma and to be inferior in flavour to wether carcasses up to a slaughter weight of 45 kg. Crouse *et al.* (1983) reported the "browned" and "ammonia" aromatics to be the first and second notes to be perceived from the meat of both rams and ewes. Bitter was the third note to be perceived from the meat of rams (Crouse *et al.* 1983). The meat from rams has also been reported to become more "gamey" and "sweet" with increases in slaughter weight, while the meat from ewes became more "musty" (Crouse *et al.* 1983). However, Jacobson *et al.* (1962) concluded the variation among individual animals was greater than the variation attributable to gender.

Lowe (1948) reported, over a wide range, an animal's chronological age at the time of slaughter constituted one of the major determinants of meat tenderness. Barwick (1980) concluded a consumer's best guide to eating quality was animal age, and Ramsey (1984) reported maturity had a substantial influence on palatability, particularly tenderness. Smith *et al.* (1969) reported chronological age was a meaningful indicator of lamb tenderness and overall palatability, and also indicated chronological age was more highly related to quality attributes of leg roasts and loin chops than maturity score. However, they also indicated maturity score and flank streaking were the traits most highly related to palatability, of the carcass parameters evaluated. Factors other than physiological maturity influence lean colour and bone structure, however, limiting the accuracy of these parameters as maturity indicators, but Ho *et al.* (1989) indicated lean colour and bone structure were the best indicators of physiological maturity. Pinkas *et al.* (1978) observed decreases in tenderness with advancing age in lambs 45 to 365 days of age, and Jeremiah *et al.* (1971) reported age to be related to both tenderness and cooking losses. Many other workers have demonstrated significant inverse relationships between the animal's age or physiological maturity and meat tenderness (Jeremiah 1978). However, some reports have indicated these relationships to be inconsistent or nonexistent (Jeremiah 1978). Moreover, Hunsley *et al.* (1967) reported the relationship between chronological age and tenderness not to be linear for beef, and Berry *et al.* (1971, 1972, 1974) reported tenderness measurements among beef physiological maturities

were often inconsistent. Reagan *et al.* (1976) reported increases in chronological age were related to initial and muscle fiber tenderness in older beef animals and to shear force values in all maturity groups, despite the fact they failed to observe differences in tenderness among physiological maturity groups. Such inconsistency in findings may be partially explained by the observations of Schmidt *et al.* (1968), who reported the effects of physiological maturity on meat tenderness were largely dependent upon the internal temperature to which the meat was cooked, since internal, endpoint temperatures above 60° C tended to mask tenderness differences between animals of different ages. Excellent examples of strong interactions between chronological age and endpoint cooking temperature with both beef and lamb/mutton have been demonstrated in Australian studies (Bouton and Harris 1972; Bouton *et al.* 1978). In addition, Walter *et al.* (1965) reported the effects of chronological age and physiological maturity were manifested through cooking possibly as a response of stromal (connective tissue) proteins to heat. Jeremiah *et al.* (1971) and Schonfeldt *et al.* (1993a,b) observed increases in lamb chronological age increased cooking losses and decreased tenderness and reported cooking losses were inversely related to juiciness. Consequently, the detrimental affects of advancing chronological age or physiological maturity on tenderness may be manifested through a drying effect during cooking.

Composite findings, to date, imply carcasses from young or youthful animals are generally likely to be more tender than carcasses from older more mature animals. However, neither chronological age nor physiological maturity can be used as accurate predictors of meat tenderness, despite the fact Reagan *et al.* (1976) concluded chronological age was one of the most important determinants of tenderness variability. Although older and more mature animals have been reported to contain a lower proportion of moisture in their carcass muscles (Jeremiah *et al.* 1997a; Reagan *et al.* 1976), differences in juiciness attributable to chronological age or physiological maturity have not been observed (Reagan *et al.* 1976). The flavour of older 68 kg ram lambs has been reported to be less desirable than the flavour of younger 41 kg ram lambs (Field *et al.* 1978). Other workers have observed flavour intensity to increase (Weller *et al.* 1962; Paul *et al.* 1964a) and flavour desirability to decrease (Misock *et al.* 1976) with advancing age in lambs at very heavy weight (80 kg). However the reported correlations between chronological age and flavour desirability (Misock *et al.* 1976) were very low, and there was no leaner trend. Crouse *et al.* (1982) indicated maturity was not related to lamb flavour, and Paul *et al.* (1964a,b,c) failed to detect age differences in flavour between wethers 5.5 and 11.5 months of age. Jacobson *et al.* (1962) concluded the variation among individual animals was greater than the variation due to age. Berry *et al.* (1974) reported all physiological maturity indicators were significantly related to palatability and indicated youthful carcasses generally received higher palatability ratings. However, Jennings *et al.* (1976) reported physiological maturity determined from lean or bone indicators affected palatability only to a slight extent. Various reports have indicated cooking losses increased (Jeremiah *et al.* 1971), tenderness decreased (Pinkas *et al.* 1978; Jeremiah et al. 1971), and flavour intensity increased (Weller *et al.* 1962; Paul *et al.* 1964a) with advancing age or physiological maturity. Other reports have indicated chronological age or physiological maturity did not influence juiciness (Reagan *et al.* 1976) or flavour (Paul *et al.* 1964a; Crouse *et al.* 1982).

A recent study involving 1660 lambs in three gender groups (rams, ewes, and wethers), three chronological age groups, and four slaughter weight groups was conducted to evaluate the effects of these inherent factors on indicators of physiological maturity and the relationships of these inherent factors with cooking palatability and consumer acceptance traits (Jeremiah *et al.* 1997d). Ewes were more physiologically mature based upon dentition, despite a previous report dentition was not gender dependant (Ho *et al.* 1989). Sacral ossification and rib colour scores were most highly related to chronological age, but accounted for only 22 and 16% of the variation in chronological age, respectively. Breakjoint score was the only physiological maturity indicator not related to chronological age. Ewe carcasses generally had the flattest ribs, the least amount of colour on their ribs, and the highest incidence of spooljoints at older ages (>9 months) and heavyweights (>68.2 kg live). The ribs of heavyweight ram carcasses (>50.0 kg live) became whiter with advancing age. Relationships of physiological maturity indicators with cooking palatability, and consumer acceptance traits indicated as lambs matured physiologically, the meat required longer cooking times, sustained greater drip and evaporative cooking losses and became more juicy but less tender. In addition, connective tissue became more perceptible and lamb flavour intensified. However, these changes resulted in only a slight reduction in consumer acceptance, probably of little practical importance.

It is readily apparent from the literature a considerable amount of research has been conducted

to examine the effects of inherent factors such as chronological age, slaughter weight, and gender on cooking properties and palatability attributes of lamb. However, the research has resulted in a considerable amount of controversy in the literature, undoubtedly due to the fact most previous studies have used relatively small, select populations and have examined one or two factors in isolation.

The cooking properties and palatability attributes were determined on loin roasts from 1660 lambs varying in chronological age, slaughter weight, and gender to be representative of the Canadian market lamb population, in a recent Lacombe study (Jeremiah *et al.* 1998a). Few meaningful differences attributable to gender were detected in cooking properties. However, in general, roasts from ram lambs were the least tender and roasts from ewe lambs were the most tender. Roasts from ewe lambs, also, generally had the least amount of perceptible connective tissue, and roasts from ram lambs had the most. Cooking drip and total cooking losses were generally not related to chronological age but increased with slaughter weight in roasts from young rams (≤6 months) and increased in roasts from ewes and wethers 6 to 9 months of age and wethers 12 to 15 months of age. Cooking times generally decreased with slaughter weight and chronological age in lightweight ram (≤49.5 kg) and wether (≤40.4 kg) lambs. Perceived degree of doneness, at the same temperature endpoint, decreased with slaughter weight in roasts from lambs 9 to 12 months of age and with advancing age in roasts from heavyweight rams and wethers (≤50 kg), but increased with advancing age in roasts from lightweight wethers (≤40.4 kg). Shear force values generally decreased and initial tenderness generally increased with slaughter weight, except in roasts from older rams (≥12 months), where the opposite effect was observed. Shear force values generally decreased and initial tenderness generally increased with advancing age in roasts from heavyweight lambs (≥50 kg). Overall tenderness generally increased with slaughter weight and decreased with advancing age. Although amount of perceptible connective tissue was generally not related to chronological age, it generally decreased with slaughter weight, except in roasts from older ram lambs, where it increased. Juiciness generally increased with advancing age and decreased with slaughter weight in roasts from older ram lambs (≥6 months). flavour intensity generally increased with slaughter weight in roasts from ram and wether lambs, except in roasts from older ram lambs (≥12 months), where it decreased. It also generally increased with advancing age, except in roasts from lightweight wether lambs (≤40.4 kg), where it decreased.

In another recent Lacombe study, a sample of 90 boneless shoulder roasts representative of the Canadian market lamb population was evaluated for flavour and texture using the profiling approach (Jeremiah *et al.* 1998b). Results revealed the following findings: 1) ram lambs had a less appropriate, well-balanced, and well-blended texture than ewe lambs, 2) wether lambs had a less appropriate, well balanced, well-blended flavour than both ram and ewe lambs, 3) the overall texture of lamb deteriorated progressively with advancing age, 4) the flavour of lambs in the mid-age groups (6 to 9 and 9 to 12 months) was more appropriate, well-balanced, and well-blended than that of older and younger lambs, 5) the overall texture of lambs improved progressively as slaughter weight increased, 6) lambs weighing over 50 kg at the time of slaughter had a more appropriate, well-balanced, and well-blended texture than lighter weight lambs, and 7) increasing slaughter weight produced beneficial effects on components of flavour, despite the fact differences in flavour amplitude attributable to slaughter weight and a significant trend in overall flavour with increasing slaughter weight were not detected.

Consumer Acceptance

Although Mendenhall and Erchanbrack (1979) reported the flavour of lamb from all genders, slaughtered between 41 and 71 kg, to be highly acceptable to consumers, Jeremiah *et al.* (1993) reported the population of Canadian market lambs was too fat to satisfy the vast majority of consumers. In addition, significant differences in lamb palatability attributable to chronological age, slaughter weight and gender have been demonstrated (Jeremiah *et al.* 1998a,b), despite the fact a considerable amount of controversy exists within the literature regarding the effects of these factors on lamb palatability. A portion of the inconsistency in reported findings is probably attributable to age/weight/gender interactions. Crouse (1983) concluded, after reviewing the literature, gender x slaughter weight interactions exerted important influences upon lamb palatability. However, very few studies have attempted to determine the influences of chronological age, slaughter weight and gender on the consumer acceptance of lamb. A recent Lacombe study was undertaken for this purpose, using a representative sample of the Canadian market lamb

population (Jeremiah *et al.* 1998c). A total of 1660 shank and 1660 butt leg roasts were distributed to lamb consuming households in 21 central Alberta regions for the evaluation of acceptability of specific palatability attributes. A total of 1528 and 1529 responses respectively were obtained for shank and butt roasts. Shank roasts from the midweight group (40.5 to 67.7 kg) were rated highest in flavour, juiciness and overall palatability. Butt roasts from ewe lambs were more acceptable in flavour and overall palatability than their counterparts from rams and wethers, respectively. However, these differences were only of marginal practical significance at best. Over 82% of all roasts were rated slightly acceptable or better in all palatability traits and less than 11% were rated slightly unacceptable or worse. The highest proportion of unacceptable ratings were for tenderness. However, over 10% of the shank roasts from rams up to 50 kg in slaughter weight and ewes up to 40.4 kg in slaughter weight were unacceptable in flavour. Roasts from rams consistently received the highest proportion of unacceptable ratings. A relatively high proportion (19.2%) of ewe shank roasts and ram butt roasts from lambs up to 40.4 kg at slaughter were unacceptable in juiciness, and over 10% of all shank roasts from lambs under 58.9 and over 67.7 kg at slaughter were unacceptable in tenderness. In addition over 11% of the shank roasts from rams up to 58.6 and wethers up to 40.4 kg at slaughter were unacceptable in overall palatability. Consequently from a consumer acceptance standpoint, based upon palatability, the most appropriate slaughter weights for market lambs is between 58.6 and 67.7 kg. However, it appears probable this conclusion may be a function of an interactive effect of physiological maturity and fatness, rather than slaughter weight per se, since this weight range probably contains animals with the optimum balance of maturity and fatness. Therefore, it does not appear prudent to control slaughter weight in a carcass grading system.

Summary and Conclusion

The lamb industry has been confronted with progressively declining per capita consumption over the past several decades. Therefore, for the industry to survive, it will be necessary to halt this trend, and if the industry is to prosper this trend must be reversed. Since the ultimate determinant of the success of any industry is consumer acceptance of its products, it is clear the industry must produce and market younger and leaner lambs. To achieve this goal it will be necessary to be cognizant of the interactions existing between biological type, chronological age, slaughter weight, and gender in the utilization of genetics and nutritional regimes to produce lambs with maximum consumer appeal and to market lambs between three and twelve months of age at slaughter weights between 59 and 68 kg. Effective classification of carcasses for both quality and yield will also substantially augment this effort.

Acknowlegement

The author is grateful to Loree Verquin and Kelly Levesque for typing the manuscript.

References

Adams, N.J.; Carpenter, Z.L.; and Spaeth, C.W. 1970. Estimation of lamb carcass composition by use of specific gravity measurements. *J. Anim. Sci.* **31**, 1081-1088.

Adams, N.A.; Carpenter, Z.L.; Spaeth, C.W.; and King, G.T. 1967. Specific gravity estimates of lamb carcass composition. *J. Anim. Sci.* **26**, 892 (Abstr.).

Alvi, A.S. 1980. The influence of sex status on meat quality characteristics in sheep. *Fleischwirtschaft* **60**, 2067-2073.

Andrews, R.P.; and Orskov, E.R. 1970. The nutrition of early weaned lamb. II. The effect of dietary protein concentration feeding level, and sex on body composition of two liveweights. *J. Agric. Sci.* (Camb.) **75**, 19-26.

Anonymous. 1984. Putting the case for ram lamb. *Meat Ind.*, U.K. **57**(4), 22-23.

Barwick, S.A. 1980. Carcass measurements and their association with yield of cuts and tenderness in lamb. *Wool Technol. Sheep Breed.* **28**, 19-23.

Barton, R.A.and Kirton, A.H. 1958. Carcass weight as an indicator of carcass components with particular reference to fat. *J. Agric. Sci.* (Camb.) **50**,331-334.

Batcher, O.M.; Brant, A.W.; and Kunge, M.S. 1969. Sensory evaluation of lamb and yearling mutton flavors. *J. Food Sci.* **34**, 272-274.

Berry, B.W.; Smith, G.C.; and Carpenter, Z.L. 1971. Histological and tenderness characteristics of beef muscles as affected by carcass maturity. *Beef Cattle Res. Texas, PR 2985, Dept. Anim. Sci., Texas A&M Univ., College Station, TX*, p. 72-73.

Berry, B.W.; Smith, G.C.; and Carpenter, Z.L. 1972. Influence of certain physiological maturity indicators on beef tenderness. *Beef Cattle Res. Texas: PR 3131, Dept. Anim. Sci., Texas A&M Univ., College Station, TX* p. 59-61.

Berry, B.W.; Smith, G.C.; and Carpenter, Z.L. 1974. Beef carcass maturity indicators and palatability attributes. *J. Anim. Sci.* **38**, 507-514.

Bouton, P.E.; and Harris, P.V. 1972. The effects of cooking temperature and time on some mechanical properties of meat. J. Food Sci., **37**, 140-144.

Bouton, P.E.; Harris, P.V.; Ratcliff, D.; and Roberts, D.W. 1978. Shear force measurements on cooked meat from sheep of various ages. *J. Food Sci.* **43**, 1038-1039.

Boylon, W.J.; and Seale, M.E. 1965. Relationships and variation among certain lamb carcass traits. *Can. J. Anim. Sci.* **45**, 37-42.

Bruwer, G.G.; Naude, R.T.; Du Toit, M.M.; Cloete, A.; and Vosloo, W.A. 1987. An evaluation of the lamb and mutton carcass grading system in the Republic of South Africa. 2. The use of fat measurements as predictors of carcase composition. *S. Afr. J. Anim. Sci.* **17**, 85-89.

Burton, J.H.; and Reid, J.T. 1969. Interrelationships among energy input, body size, age, and body composition in sheep. *J. Nutr.* **97**, 517-524.

Busboom, J.R.; Miller, G.J.; Field, R.A.; Crouse, J.D.; Riley, M.L.; Nelms, G.E.; and Ferrell, C.L. 1981. Characteristics of fat from heavy ram and wether lambs. *J. Anim. Sci.* **52**, 83-92.

Butterfield, R.M.; Reddacliff, K.J.; Thompson, J.M.; Zamora, J.; and Williams, J. 1984. Changes in body composition relative to weight and maturity of Australian Dorset Horn rams and wethers. 2. Individual muscles and muscle groups. *Anim. Prod.* 39: 259-267.

Butler-Hogg, B.W.; Francombe, M.A.; and Dransfield, E. 1984. Carcass and meat quality of ram and ewe lambs. *Anim. Prod.* **39**, 107-113.

Butler-Hogg, B.W.; Francombe, M.A.; Tempest, W.M.; and Minter, C. 1985. Carcass and meat quality of spring and hogget lamb. *Brit. Soc. Anim. Prod.*, Note, March 27, London, England.

Carpenter, Z.L. 1966. What is consumer-preferred lamb? *J. Anim. Sci.* **25**, 1232-1235.

Carpenter, Z.L.; and King, G.T. 1965a. Cooking method, marbling and color as related to tenderness of lamb. *J. Anim. Sci.* **24**, 291 (Abstr.).

Carpenter, Z.L.; and King, G.T. 1965b. Factors influencing quality of lamb carcasses. *J. Anim. Sci.* **24**, 861 (Abstr.).

Carpenter, Z.L.; King, G.T.; Orts, F.A.; and Cunningham, N.L. 1964. Factors influencing retail carcass value of lambs. *J. Anim. Sci.* **23**, 741-745.

Carpenter, Z.L.; King, G.T.; and Shelton, M. 1965. Determinants of lamb carcass cutability. *J. Anim. Sci.* **24**, 861 (Abstr.).

Carpenter, Z.L.; King, G.T.; Shelton, M.; and Butler, O.D. 1969. Indices for estimating cutability of wether, ram, and ewe lamb carcasses. *J. Anim. Sci.* **28**, 180-186.

Chadwick, J.P.; Kempster, A.J.; and Homer, D.L.M. 1986. A comparison of the Hennessey lamb probe and visual fat scores for use in sheep carcass classification. *Anim. Prod.* **42**, 445 (Abstr.).

Channon, H. 1990. Survey of retail meat butchers' attitudes to using larger and leaner lamb carcasses. *Dept. Agric. Rural Affairs, Melbourne*, Rept., No. 106, Melbourne, Australia, 82 pp.

Charlet, P. 1969. The production of meat from male animals in France *in*: Meat Production from Entire Animals. Rhodes, D.N. ed. p. 143-152, J.A. Churchill, London, England.

Chrystall, B.B.; and Winger, R.J. 1986. Composition of New Zealand lamb as influenced by geographical area, sex of animal, and cut. *Meat Ind. Res. Inst. N.Z.*, Publ. No. 842, Hamilton, N.Z.

Cramer, D.A. 1983. Chemical components implicated in lamb flavor. *Food Technol.* **37**, 249-257.

Cramer, D.A.; Pruett, J.B.; Kattning, R.M.; and Schwartz, W.C. 1970. Comparing breeds of sheep. I. flavor differences. *Proc. West. Sect. Am. Soc. Anim. Sci.* **21**, 267-272.

Crouse, J.D. 1983. The effects of breed, sex, slaughter weight, and age on lamb flavour. *Food Technol.* **37**, 264-268.

Crouse, J.D.; Busboom, J.R.; Field, R.A.; and Ferrell, C.L. 1981. The effects of breed, diet, sex, location, and slaughter weight on lamb growth, carcass composition, and meat flavor. *J. Anim. Sci.* **53**, 376-386.

Crouse, J.D.; Ferrell, C.L.; and Cross, H.R. 1983. The effects of dietary ingredients, sex, and slaughter weight on cooked meat flavor profiles of market lamb. *J. Anim. Sci.* **57**, 1146-1153.

Crouse, J.D.; Ferrell, C.L.; Field, R.A.; Busboom, J.R.; and Miller, G.J. 1982. The relationship of fatty acid composition and carcass characteristics to meat flavor in lamb. *J. Food Qual.* **5**, 203-214.

Crouse, J.D.; Field, R.A.; Chant, J.L., Jr.; Ferrell, C.L.; Smith, G.M.; and Harrison, V.L. 1978. Effect of dietary energy intake on carcass composition and palatability of different weight carcasses from ewe and ram lambs. *J. Anim. Sci.* **47**, 1207-1218.

Cunningham, N.L.; Carpenter, Z.L.; King, G.T.; Butler, O.D.; and Shelton, J.M. 1967. Relationship of linear measurements and certain carcass characteristics to retail value, quality, and tenderness of ewe, wether, and ram lambs. *J. Anim. Sci.* **26**, 683-687.

Dransfield, E.; Nute, G.R.; Butler-Hogg, B.W.; and Walters, B.R. 1990. Carcass and eating quality of ram, castrated ram and ewe lambs. *Anim. Prod.* **50**, 291-300.

Dunsing, M. 1959. Consumer preferences for beef of different breeds related to carcass and to quality grades. *Food Technol.* **13**, 516-520.

Field, R.A. 1971. Effect of castration on meat quality and quantity. *J. Anim. Sci.* **32**, 849-858.

Field, R.A.; Kemp, J.D.; and Varney, W.Y. 1963. Indices for lamb carcass composition. *J. Anim. Sci.* **22**, 218-221.

Field, R.A.; Riley, M.L.; and Botkin, M.P. 1967. Effect of sex and weight on composition of lamb. *Proc. West. Sect. An. Soc. Anim. Sci.* **18**, 46-48.

Field, R.A.; Vimini, R.J.; Crouse, J.D.; and Busboom, J.R. 1982. *Unpublished data.* University of Wyoming, Laramie, WY.

Field, R.A.; Williams, J.C.; Ferrell, C.L.; Crouse, J.D.; and Kunsman, J.E. 1978. Dietary alteration of palatability and fatty acids in meat from light and heavy weight ram lambs. *J. Anim. Sci.* **47**, 858-864.

Fienup, D.F.; Mates, W.C.; Hiemstra, S.J.; and Laubis, R.L. 1963. Economic effects of U.S. grades for lamb. *U.S.D.A. Econ. Res. Serv. Agric. Econ.* Rept. No. 25, Marketing Economics Division, Washington, D.C.

Forrest, J.C. 1962. Relationship of subjective indices of quality in lamb carcasses to objective measurements of quality and grade. M.S. thesis, Kansas St. University, Manhattan, KS.

Fox, C.W.; McArthur, J.A.B.; and Sather, L. 1962. Effect of sire and breed on flavour scores from weanling lambs. *Proc. West. Sect. Am. Soc. Anim. Sci.* **13**, 37-38.

Garrett, R.P.; Edwards, J.W.; Savell, J.W.; and Tatum, J.D. 1992. Evaluation of the Hennessey grading probe to predict yields of lamb carcasses fabricated to multiple end points. *J. Anim. Sci.* **70**, 1146-1152.

Garrigus, U.S.; Vatthauer, R.J.; Hatfield, E.E.; Doane, B.B.; Sokolouski, J.H.; and Usborne, W.R. 1962. Some effects of sex on rate of gain and carcass quality of young lambs. *Proc. West. Sect. Am. Soc. Anim. Sci.* **13**, 39-40.

Gates, T.R.; Orme, L.E.; Christain, R.E.; Bell, T.D.; and Everson, D.O. 1964. Tenderness, flavour, and chemical composition of lambs as influenced by breed and sex. *Proc. West. Sect. Am. Soc. Anim. Sci.* **15**, 661-662.

Hankins, O.G. 1947. Estimation of the composition of lamb carcasses and cuts. U.S.D.A. Tech. Bull. No. 944, Washington, D.C.

Ho, L.; Field, R.A.; Russell, W.C.; Riley, M.L.; Ercanbrack, S.K.; and Williams, F.L., Jr. 1989. Influence of gender, breed, and age on maturity characteristics of sheep. *J. Anim. Sci.* **67**, 2460-2470.

Hodge, R.W.; and Oddie, N. 1984. Prediction of bone-in retail cuts and edible meat from crossbred lamb carcasses. *Aust. J. Exp. Agric. Anim. Husb.* **24**, 344-349.

Hoke, K.E. 1961. Factors affecting yield of cuts in lamb carcasses. *Proc. Recip. Meat Conf.* **14**, 163-166.

Hopkins, D.L. 1994. Predicting the weight of lean meat in lamb carcasses and the suitability of this characteristic as a basis for valuing carcasses. *Meat Sci.* **38**, 235-241.

Hopkins, D.L.; Anderson, M.A.; Morgan, J.E.; and Hall, D.G. 1993. A probe to measure GR in lamb carcasses at chain speed. *Meat Sci.* **39**, 159-165.

Hopkins, D.L.; and Fogarty, N.M. 1998a. Diverse lamb genotypes. 1. Yield of saleable cuts and meat in the carcass and the prediction of yield. *Meat Sci.* **49**, 459-475.

Hopkins, D.L.; and Fogarty, N.M. 1998b. Diverse lamb genotypes. 2. Meat pH, colour, and tenderness. *Meat Sci.* **49**, 477-488.

Hopkins,D.L.; Pirlot, K.L.; and Gittens, R. 1992. Consumer attitudes to selected lamb cuts. *Meat Sci.* **32**, 407-412.

Hunsley, R.E.; Vetter, R.L.; Kline, E.A.; and Burroughs, W. 1967. Effects of age and sex on quality, tenderness, and collagen content of bovine *longissimus dorsi* muscle. *J. Anim. Sci.* **26**, 1469 (Abstr.).

Jabet, S. 1993. Meat quality aspects of lamb carcasses with soft coloured fat. *Viantes et Produits Carnes* **14**, 63-67.

Jacobs, J.A. 1972. The effects of sex, weight, and stress on carcass composition, fatty acid variability, and organoleptic evaluation of lamb. *Dissert. Abstr. Intern.* B. **33**, 5.

Jacobs, J.A.; Field, R.A.; Botkin, M.P.; Riley, M.L.; and Roehrkasse, G.P. 1972. Effects of weight and castration on lamb carcass composition and quality. *J. Anim. Sci.* **35**, 926-930.

Jacobson, M.; Weller, M.; Galgan, M.W.; and Rupnow, E.H. 1962. Factors in flavour and tenderness of lamb, beef, and pork, and techniques of evaluation. Wash. Agric. Expt. Stn. Tech. Bull. No. 40, Pullman, WA.

Jennings, T.G.; Berry, B.W.; and Buchanan, A. 1976. Fat thickness, marbling, and aging. 1. Effects on palatability. *J. Anim. Sci.* **43**, 240-241 (Abstr.).

Jeremiah, L.E. 1978. A review of factors affecting meat quality. Lacombe Res. Stn. Tech. Bull. No. 1, Lacombe, AB.

Jeremiah, L.E. 1982. A review of factors influencing consumption, selection and acceptability of meat purchases. *J. Cons. Stud. Home Econ.* **6**, 137-154.

Jeremiah, L.E. 1988. A comparison of flavour and texture profiles for lamb leg roasts from three different geographical sources. *Can. Inst. Food Sci. Technol. J.* **21**, 471-476.

Jeremiah, L.E. 1998. Development of a quality classification system for lamb carcasses. *Meat Sci.* **48**, 211-223.

Jeremiah, L.E.; Gibson, L.L.; and Tong, A.K.W. 1993. Retail acceptability of lamb as influenced by gender and slaughter weight. *Food Res. Int.* **26**, 115-118.

Jeremiah, L.E.; Jones, S.D.M.; Tong, A.K.W.; Robertson, W.M.; and Gibson, L.L. 1997a. The influence of lamb chronological age, slaughter weight, and gender on carcass composition. *Sheep Goat Res. J.* **13**, 30-38.

Jeremiah, L.E., Jones, S.D.M.; Tong, A.K.W.; Robertson, W.M.; and Gibson, L.L. 1997b. The influence of lamb chronological age, slaughter weight and gender on yield and cutability. *Sheep Goat Res. J.* **13**, 39-49.

Jeremiah, L.E.; Jones, S.D.M.; Tong, A.K.W.; and Gibson, L.L. 1997c. The influence of lamb chronological age, slaughter weight and gender on carcass measurements. *Sheep Goat Res. J.* **13**, 87-95.

Jeremiah, L.E.; Smith, G.C.; and Carpenter, Z.L. 1972. Ovine yield grades. II. Palatability attributes within various quality grades. *J. Anim. Sci.* **34**, 196-202.

Jeremiah, L.E.; Smith, G.C.; and Carpenter, Z.L. 1971. Palatability of individual muscles from ovine leg steaks as related to chronological age and marbling. *J. Food Sci.* **35**, 45-47.

Jeremiah, L.E.; Tong, A.K.W.; and Gibson, L.L. 1997d. The influence of lamb chronological age, slaughter weight, and gender on physiological maturity indicators. *Sheep Goat Res. J.* **13**, 96-104.

Jeremiah, L.E.; Tong, A.K.W.; and Gibson, L.L. 1997e. The influence of lamb chronological age, slaughter weight, and gender on carcass and meat quality. *Sheep Goat Res. J.* **13**, 157-166.

Jeremiah, L.E.; Tong, A.K.W.; and Gibson, L.L. 1998a. The influence of lamb chronological age, slaughter weight, and gender on cooking properties and palatability. *Sheep Goat Res. J.* **14**, 156-166.

Jeremiah, L.E.; Tong, A.K.W.; and Gibson, L.L. 1998b. The influence of lamb chronological age, slaughter weight, and gender. Flavor and texture profiles. *Food Res. Int.* **31**, 227-242.

Jeremiah, L.E.; Tong, A.K.W.; and Gibson, L.L. 1998c. The influence of lamb chronological age, slaughter weight and gender on consumer acceptance. *Sheep Goat Res. J.* **14**, 206-213.

Johnston, D.D.; Tyler, W.E.; Murphey, C.E.; Kimbrell, E.F.; Manns, D.F.; Strong, C.L.; Carpenter, Z.L.; and King, G.T. 1967. Estimating yields of retail cuts from lamb carcasses. *J. Anim. Sci.* **26**, 896 (Abstr.).

Jones, S.D.M.; Jeremiah, L.E.; Tong, A.K.W.; Robertson, W.M.; and Gibson, L.L. 1992. Estimation of lamb carcass composition using an electronic probe, a visual scoring system and carcass measurements. *Can. J. Anim. Sci.* **72**, 237-244.

Jones, S.D.M.; Robertson, W.M.; Price, M.A.; and Coupland, T. 1996. The prediction of saleable meat yield in lamb carcasses. *Can. J. Anim. Sci.* **76**, 49-53.

Judge, M.D.; and Martin, T.G. 1963. Prediction of lamb carcass composition from carcass weights and measurements. J. *Anim. Sci.* **22**, 828 (Abstr.).

Judge, M.D.; Martin, T.G.; and Outhouse, J.B. 1966. Prediction of carcass composition of ewe and wether lambs from carcass weights and measurements. *J. Anim. Sci.* **25**, 92-95.

Kemp, J.D.; Field, R.A.; Varney, N.Y.; and Woolfolk, P.G. 1962. The effect of sex and type of scoring on carcass characteristics of Southdron sired lambs. KY. Agric. Expt. Stn.Prog. Rept. No. 116, Lexington, KY.

Kemp, J.D.; Johnson, A.E.; Stewart, D.F.; Ely, D.G.; and Fox, J.D. 1976. Effect of dietary protein, slaughter weight, and sex on carcass composition, organoleptic properties, and cooking losses of lamb. *J. Anim. Sci.* **42**, 575-583.

Kemp, J.D.; Shelley, J.M., Jr.; Ely, D.G.; and Moody, W.G. 1972. Effects of castration and slaughter weight on fatness, cooking losses, and palatability of lamb. *J. Anim. Sci.* **34**, 560-562.

Kempster, A.J.; Avis, P.R.D.; Cuthbertson, A.; and Harrington, G. 1976. Prediction of the lean content of lamb carcasses of different breed types.A review. J. *Agric. Sci.* (Camb.) **86**, 23-34.

Kempster, A.J.; Chadwick, J.P.; Cue, R.I.; and Grantley-Smith, M. 1986. The estimation of sheep carcass composition from fat and muscle thickness measurements taken by probes. *Meat Sci.* **16**, 113-126.

Kempster, A.J.; Cuthbertson, A.; and Harrington, G. 1982. The relationship between conformation and the yield and distribution of lean meat in the carcasses of British pigs, cattle, and sheep. *Meat Sci.* **6**, 37-53.

Khandekar, V.N.; McManus, W.R.; and Goldstone, C.L. 1965. Some indices of the carcass composition of Dorset Horn Top-Cross lambs. II. Specific gravity as an index of the fat content of the carcass and of various joints. *J. Agric. Sci.* (Camb.) **65**, 155-158.

Kirton, A.H.; Clarke, J.N.; and Hickey, S.M. 1982. A comparison of the composition and carcass quality of Kelly and Russian castrate ram, wether, and ewe lambs. *Proc. N.Z. Soc. Anim. Prod.* **42**, 117-118.

Kirton, A.H.; Mercer, G.J.K.; Duganzich, D.M.; and Uljie, A.E. 1995. Use of electronic probes for classifying lamb carcasses. *Meat Sci.* **39**, 167-176.

Kirton, A.H.; Woods, E.G.; and Duganzich, D.M. 1984. Predicting the fatness of lamb carcasses from carcass wall thickness measured by ruler or by a Total Depth Indicator (TDI) probe. *Livest. Prod. Sci.* **11**, 185-194.

Knight, A.D.; and Foote, W.C. 1965. Influence of breed-type, feed level, and sex on lamb carcass characteristics. *J. Anim. Sci.* **24**, 786-789.

Kruggel, W.G.; Field, R.A.; Miller, G.J.; Horton, K.M.; and Busboom, J.R. 1982. Influence of sex and diet on lutein in lamb fat. J. Anim. Sci. **54**, 970-975.

Lane, J.P.; and Walters, L.E. 1958. Acceptability studies in beef. Okla. Agric. Expt. Stn. Bull. No. P-305, Stillwater, OK.

Lewczuk, A.; Bochno, R.; and Kuchtan, T. 1980. Suitability of body weight and dimensions in Polish longwool sheep of different ages for assessment of contents of tissue compounds in the half carcass. Zeszyty Naukowe Akademii Rolniczo-Technicznej; W. Olsztynie Zootechnicka **20**, 123-134.

Lowe, B. 1948. Experimental Cookery. John Wiley, New York, NY.

Mendenhall, V.T.; and Ercanbrack, S.K. 1979. Influence of carcass weight, sex, and breed on consumer acceptance of lamb. *J. Food Sci.* **44**, 1063-1066.

Misock, J.P.; Campion, D.R.; Field, R.A.; and Riley, M.L. 1976. Palatability of heavy ram lambs. *J. Anim. Sci.* **42**, 1440-1444.

Moody, W.G.; Zobrisky, S.E.; Ross, C.V.; and Naumann, H.D. 1965. Ultrasonic measurements of fat thickness and *longissimus dorsi* area in lamb. *J. Anim. Sci.* **24**, 364-367.

Munson, A.W.; Whiteman, J.V.; and Walters, L.E. 1966. A method for estimating ether extract in the boneless portion of lamb carcasses. *J. Anim. Sci.* **25**, 967-971.

Naumann, H.D.; Braschler, C.; Mangel, M.; and Rhodes V.J. 1961. Consumer and laboratory evaluation of Good and Choice beef loins. Mo. Agric. Expt. Stn. Res. Bull. No. 777, Columbia, MO.

Notter, D.R.; Ferrell, C.L.; and Field, R.A. 1983. Effect of breed and intake level on allometric growth patterns in ram lambs. J. *Anim. Sci.* **56**, 380-395.

Oliver, W.M.; Carpenter, Z.L.; King, G.T.; and Shelton, M. 1968. Predicting cutability of lamb carcasses from carcass weights and measures. *J. Anim. Sci.* **27**, 1254-1260.

Oliver, W.M.; Carpenter, Z.L.; King, G.T.; and Shelton, J.M. 1967. Quantitative and qualitative characteristics of ram, wether, and ewe lamb carcasses. *J. Anim. Sci.* **26**, 307-310.

Orme, L.E.; Christian, R.E.; and Bell, T.D. 1962. Live animal and carcass indices for estimating the carcass composition in lambs. *J. Anim. Sci.* **21**, 666 (Abstr.).

Pálsson, H. 1939. Meat qualities in sheep with special reference to the Scottish Breeds and crosses. *J. Agric. Sci.* (Camb.) **29**, 544-626.

Pattie, W.A.; Godler, A.C.; and Bouton, P.E. 1964. The effect of castration and the poll gene on prime lamb production. *Aust. J. Exp. Agric. Anim. Husb.* **4**, 386-391.

Paul, P.C.; Torten, J.; and Spurlock, G.M. 1964a. Eating quality of lamb. I. Effect of age. *Food Technol.* **18**, 1779-1782.

Paul, P.C.; Torten, J.; and Spurlock, G.M. 1964b. Eating quality of lamb. II. Effect of preslaughter nutrition. *Food Technol.* **18**, 1783-1784.

Paul, P.C.; Torten, J.; and Spurlock, G.M. 1964c. Eating quality of lamb. Overall comparisons and interrelationships. *Food Technol.* **18**, 1785-1788.

Pinkas, A.; Voinova, R.; and Popovska, T.S. 1978. Changes in lamb meat tenderness as affected by postmortem biochemical modifications in myofibrillar proteins. *Zhivotnov'd Nauki* **15**, 47-53.

Pradhan, S.L.; McManus, W.R.; Goldstone, C.L.; Hart, R.F.; Khandekar, V.N.; and Arnold, G.W. 1966. Indices of the carcass composition of Dorset Horn top-carcass lambs. III. Relationship between chemical composition, specific gravity, and weight of carcasses and joints. *J. Agric. Sci.* (Camb.) **66**, 41-47.

Purchas, R.W. 1978. Some effects of nutrition and castration on meat production from male Suffolk cross (Border Leicester-Romney cross) lambs. I.

Growth and carcass quality. *N.Z. J. Agric. Res.* **21**, 367-376.

Purchas, R.W.; O'Brien, L.E.; and Pendleton, C.E. 1979. Some effects of nutrition and castration on meat production from male Suffolk cross (Border Leicester- Romney cross) lambs. II. Meat quality. *N.Z. J. Agric. Res.* **22**, 375-383.

Purchas, R.W.; and Wilkin, G.H. 1995. Characteristics of lamb carcasses of contrasting subjective muscularity. *Meat Sci.* **41**, 357-368.

Ramsey, C.B. 1984. Meat palatability as affected by nutrition of animals. *Sheep Goat Handbook* **4**, 571-580.

Ray, E.E.; and Kromann, R.P. 1971. Effect of sex, age of lamb, and length of feeding upon energy metabolism and carcass traits of lambs. *J. Anim. Sci.* **32**, 721-726.

Ray, E.E.; and Mandigo, R.W. 1963. Factors affecting retail value of lamb carcasses. N.M. Agric. Expt. Stn. Res. Rept. No. 86, Las Cruces, NM.

Ray, E.E.; and Mandigo, R.W. 1966. Genetic and environmental factors affecting carcass traits of lambs. *J. Anim. Sci.* **25**, 449-453.

Reagan, J.O.; Carpenter, Z.L.; and Smith, G.C. 1976. Age-related traits affecting the tenderness of the bovine *longissimus* muscle. *J. Anim. Sci.* **43**, 1198-1205.

Riley, M.L.; Field, R.A.; and Botkin, M.P. 1972. The effect of breed and age on carcass traits of lambs. *J. Anim. Sci.* **34**, 891 (Abstr.).

Ringkob, T.P.; Zobrisky, S.E.; Ross, C.V.; and Naumann, H.D. 1964. Measurements of muscle and retail cuts of lamb. Mo. Agric. Expt. Stn. Res. Bull. No. 876, Columbia, MO.

Sañudo, C.; Santolaria, M.P.; María, G.; Osorio, M.; and Sierra, I. 1996. Influence of carcass weight on instrumental and sensory lamb meat quality in intensive production systems. *Meat Sci.* **42**, 195-202.

Sañudo, C.; Nute, G.R.; Campo, M.M.; María, G.; Baker, A.; Sierra, I.; Enser, M.E.; and Wood, J.D. 1998. Assessment of commercial lamb meat quality by British and Spanish taste panels. *Meat Sci.* **48**, 91-100.

Schmidt, J.G.; Kline, E.A.; and Parrish, F.C., Jr. 1968. Effects of carcass maturity and heating on bovine *L. dorsi* muscle. *J. Anim. Sci.* **27**, 1764-1765. (Abstr.)

Schönfeldt, H.C.; Naudé, R.T.; Bok, W.; van Heerden, S.M.; Smit, R.; and Boshoff, E. 1993a. Flavour and tenderness related quality characteristics of goat and sheep meat. *Meat Sci.* **34**, 363-379.

Schnöfeldt, H.C.; Naudé, R.T.; Bok, W.; van Heerden, S.M.; and Sowden, L. 1993b. Cooking and juiciness related quality characteristics of goat and sheep meat. *Meat Sci.* **34**, 381-394.

Seltzer, R.E. 1955. Consumer preferences for beef. Ariz. Agric. Expt. Stn. Bull. No. 267, Tucson, AZ.

Smith, G.C.; Carpenter, Z.L; King, G.T.; and Hoke, K. 1969. Lamb palatability studies. *Proc. 22nd Ann. Recip. Meat Conf.* **22**, 69-97.

Smith, G.C.; Carpenter, Z.L.; King, G.T.; and Hoke, K.E. 1970. Lamb carcass quality. I. Palatability of leg roasts. *J. Anim. Sci.* **30**, 496-502.

Spurlock, G.M.; and Bradford, G.E. 1965. Comparison of systems of lamb carcass evaluation. *J. Anim. Sci.* **24**, 1086-1091.

Spurlock, G.M.; Bradford, G.E.; and Wheat, J.D. 1966. Live animal and carcass measures for the prediction of carcass traits in lambs. *J. Anim. Sci.* **25**, 454-459.

Steele, K.; and Hohenboken, W.D. 1972. Effects of liveweight on carcass merit of lambs. *J. Anim. Sci.* **34**, 890-891. (Abstr.).

Summers, R.L.; Kemp, J.D.; Ely, D.G.; and Fox, J.D. 1978. Effects of weaning, feeding systems, and sex of lamb on lamb carcass characteristics and palatability. *J. Anim. Sci.* **47**, 622-629.

Thompson, J.M.; Atkins, K.D.; and Gilmour, A.R. 1979. Carcass characteristics of heavyweight crossbred lambs. II. Carcass composition and partitioning of fat. *Aust. J. Agric. Res.* **30**, 1207-1214.

Timon, V.M.; and Bichard, M. 1965. Quantitative estimates of lamb carcass composition. 1. Sample joints. *Anim. Prod.* **7**, 173-181.

Van Syckle, C.; and Brough, O.L., Jr. 1958. Consumer acceptance of fat characteristics of beef. Wash. Agric. Expt. Stn. Tech. Bull. No. 27, Pullman, WA.

Vesely, J.A.; and Peters, H.F. 1972. Muscle, bone, and fat in five breeds of lambs. *J. Anim. Sci.* **34**, 887 (Abstr.).

Walker, D.E. 1950. The influence of sex upon carcass quality of New Zealand fat lambs. *N.Z. J. Sci. Technol.* **32**, 30-38.

Walker, D.E.; and McMeekan, C.P. 1944. Canterbury lamb. *N.Z. J. Sci. Technol.* **A26**, 2-5.

Walter, M.J.; Goll, D.E.; Kline, E.A.; Anderson, L.P.; and Carlin, A.F. 1965. Effect of marbling and maturity on beef muscle characteristics. I. Objective measurements of tenderness and chemical properties. *Food Technol.* **19**, 841-845.

Weller, M.; Galgan, M.W.; and Jacobson, M. 1962. flavor and tenderness of lamb as influenced by age. *J. Anim. Sci.* **21**, 927-929.

Wenham, L.M.; Fairbairn, S.J.; McLeod, K.; Carse, W.A.; Pearson, A.M.; and Locker, R.H. 1973. Eating quality of mutton compared with lamb

and its relationship to freezing practice. *J. Anim. Sci.* **36**, 1081-1087.

Wiggins, J.P.; Wilson, L.L.; Rothenbacher, H.; and Davis, S.L. 1976. Effects of diethylstilbestrol, zeranol, and sex on live blood metabolite, carcass, and endocrine characteristics of lambs. *J. Anim. Sci.* **43**, 518-527.

Wilson, L.L.; Ziegler, J.H.; Rugh, M.C.; Watkins, J.L.; Merritt, T.L.; Simpson, M.J.; and Kruezberger, F.L. 1970. Comparison of live slaughter and carcass characteristics of rams, induced cryptorchids and wethers. *J. Anim. Sci.* **31**, 455-458.

Wise, J.W. 1978. The effects of sex, slaughter weight, and breed on carcass composition, fatty acid content, and tenderness of lamb. Ph.D. Dis., Univ. of Nebraska, Lincoln, NE.

Wood, J.D.; MacFie, H.J.H.; Pomeroy, R.W.; and Twinn, D.J. 1980. Carcass composition in four sheep breeds: The importance of type of breed and stage of maturity. *Anim. Prod.* **30**, 135-152.

Zinn, D.W. 1961. Cutting methods as related to lamb carcass evaluation. *Proc. 14th Ann. Recip. Meat Conf.* **14**, 177-180.